

# Superclustering at Redshift $z = 0.54$

A. J. Connolly<sup>1</sup> and A. S. Szalay<sup>1,2</sup>

Department of Physics and Astronomy, The Johns Hopkins University, Baltimore, MD  
21218

D. Koo<sup>1</sup>

University of California Observatories, Lick Observatory, Board of Astronomy and  
Astrophysics, University of California Santa Cruz, CA 95064

A. K. Romer

Dept. of Physics and Astronomy, Northwestern University, 2145 Sheridan Road, Evanston,  
IL-60208, USA.

B. Holden and R.C. Nichol

Department of Astronomy and Astrophysics, University of Chicago, 5460 S. Ellis Ave,  
Chicago, IL 60637

T. Miyaji

Max-Planck-Institut für Extraterrestrische Physik Postf. 1603, D-85740, Garching,  
Germany

---

<sup>1</sup>Visiting Astronomer, Kitt Peak National Observatory, National Optical Astronomy Observatories, operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

<sup>2</sup>Department of Physics, Eötvös University, Budapest, Hungary, H-1088

## ABSTRACT

We present strong evidence for the existence of a supercluster at a redshift of  $z = 0.54$  in the direction of Selected Area 68. From the distribution of galaxies with spectroscopic redshifts we find that there is a large over-density of galaxies (a factor of four over the number expected in an unclustered universe) within the redshift range  $0.530 < z < 0.555$ . By considering the spatial distribution of galaxies within this redshift range (using spectroscopic and photometric redshifts) we show that the galaxies in SA68 form a linear structure passing from the South-West of the survey field through to the North-East (with a position angle of approximately  $35^\circ$  East of North). This position angle is coincident with the positions of the X-ray clusters CL0016+16, RX J0018.3+1618 and a new X-ray cluster, RX J0018.8+1602, centered near the radio source 54W084. All three of these sources are at a redshift of  $z \sim 0.54$  and have position angles, derived from their X-ray photon distributions, consistent with that measured for the supercluster. Assuming a redshift of 0.54 for the distribution of galaxies and a FWHM dispersion in redshift of 0.020 this represents a coherent structure with a radial extent of  $31 \text{ h}^{-1}\text{Mpc}$ , transverse dimension of  $12 \text{ h}^{-1}\text{Mpc}$ , and a thickness of  $\sim 4 \text{ h}^{-1}\text{Mpc}$ . The detection of this possible supercluster demonstrates the power of using X-ray observations, combined with multicolor observations, to map the large scale distribution of galaxies at intermediate redshifts.

*Subject headings:* galaxies: distances and redshifts — large-scale structure of universe — techniques: photometric

## 1. Introduction

By mapping the spatial distribution of galaxies, we can determine the intrinsic scales on which galaxies cluster, from poor groups through rich clusters to superclusters. Quantifying the abundance of these clusterings and their evolution with time should provide important constraints on the multifarious cosmological models (Liddle et al. 1996). In the local universe, extensive redshift surveys have been undertaken to map the distribution of galaxies to  $B \sim 15.5$  that reach to a redshift of  $z \sim 0.05$ . Such surveys have uncovered coherent structures that extend over many tens of megaparsecs, such as the Perseus-Pisces filament (Giovanelli and Haynes 1993) or the sheet-like “Great Wall” (Geller and Huchra

1989). These structures appear to be common in other and even deeper ( $B < 20$ ) surveys that extend beyond redshifts  $z \sim 0.1$  (Landy et al. 1996, Willmer et al. 1996).

At even fainter magnitudes, redshift surveys have been undertaken to a limit of  $B \simeq 24$  (Cowie et al. 1996, Glazebrook et al. 1995, Lilly et al. 1995). Because of the long exposures required to reach such faint limits, these surveys have been restricted to a few pointings that cover tiny regions of sky, typically  $\leq 10$  arcmin in diameter. Consequently, while large over-densities of galaxies are visible in the deep redshift surveys (Broadhurst et al. 1990, Le Fevre et al. 1994, Cohen et al. 1996), the angular distribution of these structures and, therefore, their transverse spatial extent, have yet to be well studied.

In this letter we consider the distribution of galaxies in the direction of Selected Area 68 (Kron 1980). We identify this region as a potential site of an intermediate redshift supercluster because of the coherent distribution of very red galaxies, estimated to be at  $z \sim 0.5$ , found by Koo (1985) and the presence of two X-ray clusters at the same redshift (Hughes et al. 1995). The over-density of galaxies is quantified using a small sample of spectroscopic redshifts in §2 and then improved using a larger sample of photometric redshifts in §3. The coincidence of this structure with the position and orientation of three X-ray clusters is discussed in §4. Finally we show that the galaxies and clusters are consistent with a “Great Wall”-like supercluster, at  $z = 0.54$ , that is almost edge-on with respect to the line of sight. For this letter we assume an  $H_o = 100 \text{ km s}^{-1} \text{ Mpc}^{-1}$  and  $\Omega = 1$  cosmology; at redshift  $z \sim 0.54$ , the lookback time is nearly half the age of the universe and one degree spans  $13.5 \text{ h}^{-1} \text{ Mpc}$ .

## 2. The Distribution of Spectroscopic Redshifts in the Selected Area SA68

To determine if there exist intermediate redshift counterparts to the locally detected superclusters, we consider the spectroscopic and photometric galaxy catalog of Koo and Kron (Kron 1980, Koo 1986, Munn et al. 1996) in the direction of Selected Area 68 ( $00^{\text{hr}}14^{\text{m}} + 15^{\circ}30^{\text{m}}$ ). These data comprise a total of 1750 galaxies,  $B_J < 23.0$ , with multicolor photometry in the  $U, B_J, R_F$  and  $I_N$  passbands. Of these galaxies 286 have spectroscopically measured redshifts.

In Fig 1 we show the redshift distribution of the spectroscopic sample of galaxies. The most striking features of this redshift distribution are the regular set of peaks. Such over-densities have been interpreted as the intersection of the narrow pencil beam surveys with large-scale coherent structures in the galaxy distribution (Broadhurst et al. 1990, Szalay et al. 1991, Le Fevre et al. 1994, Cohen et al. 1996). For later discussions, we consider

only the spatial and redshift distribution of those galaxies lying between  $0.530 < z < 0.555$ .

To test whether this feature, at  $z = 0.55$ , represents a significant perturbation from number of galaxies expected from an unclustered distribution of galaxies, we calculate the selection function for the spectroscopic sample of galaxies. As the spectroscopic sample is not formally magnitude limited we must calculate the expected redshift distribution using the models of Gronwall and Koo (1995). These models were derived to match the observed redshift distribution of SA68 to a limit of  $B < 24$ . Taking the observed  $B_J$  magnitude distribution of the spectroscopic galaxy sample we construct the expected  $dn/dz$  (the solid line in Fig 1). The expectation value for the number of galaxies with  $0.530 < z < 0.555$  is 3.54.

To account for a clustered distribution we calculate the variance of the expectation value by integrating the local spatial correlation function,  $\xi(r)$ , over this redshift volume. Assuming a projected area of  $706 \text{ arcmin}^2$  for SA68 we estimate the variance in the expectation value to be 3.7. It should be noted that this is a conservative value (an upper limit) as we assume no evolution of the spatial correlation function, with redshift. We would, therefore, expect to detect

$$\langle N \rangle = 3.54 \pm 3.7 \quad (1)$$

galaxies with spectroscopic redshifts within the redshift range  $0.530 < z < 0.555$ . The observed number of galaxies in this redshift peak is 14, representing a factor of 4 over the unclustered expectation value. Fitting a Gaussian to the spectroscopic redshifts we determine the dispersion of the redshift distribution to be 0.0083. If the dispersion in redshift were due to the internal velocity of a cluster this would equate to a velocity dispersion of  $\sim 2500 \text{ km s}^{-1}$  far in excess of local observations (Zabludoff et al. 1993, Collins et al. 1995). The radial distance corresponding to the FWHM of the redshift distribution is then  $31 \text{ h}^{-1} \text{ Mpc}$ .

The projected angular distribution of the spectroscopic sample of galaxies within this redshift range is shown in Fig 2a. They form a linear structure passing from the South-West of the SA68 field through to the North-East. The angular distribution extends to the limits of the survey field. From the second moments of the galaxy distribution we find that this structure can be represented by an ellipse with a position angle oriented  $29^\circ$  East of North and centered on  $00^{\text{hr}}14^{\text{m}}40^{\text{s}}+15^\circ33'58''$  (B1950).

While the number of galaxies with observed spectroscopic redshifts is small we can estimate whether they are consistent with a uniform distribution of galaxies across the SA68 survey field. We do this by applying a 2 dimensional Kolmogorov-Smirnov test (Peacock 1983, Fasano and Franceschini 1987). For a sample size of 14, the probability that the

galaxies with spectroscopic redshifts are consistent with a uniform distribution is only 15%.

### 3. The Distribution of Galaxies across Selected Area SA68

Since the spectroscopic sample is so small, we adopt another technique to increase the redshift sample, namely we estimate the redshift of a galaxy from its broadband magnitudes. The effectiveness of this technique for deriving galaxy redshifts to the limit of our photometric data has been demonstrated by Connolly et al. (1995). By fitting the  $U, B_J, R_F, I_N$  magnitudes with a second order relation to the spectroscopic redshifts, redshifts can be estimated to an accuracy of  $\sigma_z \leq 0.05$ .

We calculate the photometric redshift relation for the galaxies in the photometric sample using the prescription given by Connolly et al. (1995). Comparing those galaxies with spectroscopic redshifts with their estimated photometric redshifts we derive a dispersion in the relation of  $\sigma_z = 0.049$ . We select a  $1\sigma_z$  range around the peak in the spectroscopic redshift distribution. In Fig 2b we show the distribution of the 146 galaxies within the redshift range  $0.49 < z < 0.59$ . These data have been smoothed with a kernel of diameter 2.5 arcmin ( $0.55\text{ h}^{-1}\text{Mpc}$  at  $z = 0.54$ ; equivalent to the core diameter of a King cluster profile).

The galaxy distribution is again seen to form a coherent linear structure passing from the South-West to the North-East of SA68. The second moments of the distribution of galaxies gives a position angle of  $40.3^\circ$  centered on  $00^{\text{hr}}14^{\text{m}}41^{\text{s}}+15^\circ37'16''$ . Clearly this represents an underestimate of the over-density of galaxies within the supercluster (due to the contamination from foreground and background galaxies). The two-dimensional Kolomogorov-Smirnov test yields only a 2% probability that the photometric-redshift sample is drawn from a uniform distribution. A comparison of the angular distributions of those galaxies with spectroscopic redshifts with those from the photometric redshift sample shows that the probability that they are drawn from *different* intrinsic populations is only 45% (i.e. less than a one sigma deviation). The angular distribution of the spectroscopic and photometric redshift samples, therefore, display the same large-scale clustering properties. They show a linear structure of at least 0.5 degrees in extent (equivalent to  $6.5\text{ h}^{-1}\text{Mpc}$  at  $z = 0.54$ ).

#### 4. The distribution of X-ray clusters around Selected Area SA68

Just beyond half a degree from the center of SA68 lies the X-ray luminous cluster CL0016+16 at a redshift of  $z = 0.5455$  (Koo 1981, see Fig 2), which was the target of one of the deepest ROSAT PSPC pointed observations (Hughes et al. 1995). The efficacy of using deep ROSAT pointings to serendipitously identify X-ray clusters has been demonstrated by Hughes et al. (1995). As part of the Serendipitous High-redshift Archival ROSAT Cluster (SHARC) survey (Nichol et al. 1996, Burke et al. 1996) we have, therefore, reanalyzed this deep pointing using a detection algorithm based on the wavelet transform.

In the SHARC survey, an X-ray source is flagged as a candidate distant cluster if the observed X-ray emission is significantly extended ( $> 3\sigma$ ) compared to the radial-dependent PSPC point-spread function. Furthermore, the source is required to have no optical counterpart on the Palomar Digital Sky Survey Plates. In addition to CL0016+16 ( $00^{\text{hr}}18^{\text{m}}33.2+16^{\circ}26^{\text{m}}18$ ) and RX J0018.3+1618 ( $00^{\text{hr}}18^{\text{m}}16.8+16^{\circ}17^{\text{m}}45$ , Hughes et al. 1995) - which both satisfy these criteria - we have discovered a further such X-ray source; RX J0018.8+1602 ( $00^{\text{hr}}18^{\text{m}}45.5+16^{\circ}01^{\text{m}}41$ ). This source lies 25 arcmins from the center of the PSPC pointing and is within 1 arcmin of the radio galaxy 54W084 (Neff et al. 1995).

The PSPC X-ray contours of RX J0018.8+1602 are overlaid on a  $B_J$  photographic plate (# 1286) observed by R. Kron with the KPNO 4m telescope. The peak in the X-ray photon distribution is coincident with an over-density of faint,  $B_J < 23$ , galaxies in the optical data. The color of the central optical galaxy is consistent with that of an elliptical galaxy at a redshift of 0.5. Within the X-ray contours lies the radio galaxy 54W084 at a redshift of  $z = 0.544$  (R. Windhorst, private communication); indicated by an arrow in Fig 3. If we assume a redshift of 0.544, RX J0018.8+1602 has a luminosity in the 0.500–2.0 keV energy range of  $4.25 \times 10^{43}$  ergs s $^{-1}$ . This compares with an X-ray luminosity of  $2.5 \times 10^{43}$  ergs s $^{-1}$  measured by Hughes et al. (1995) for the cluster RX J0018.3+1618. The ROSAT PSPC spectrum of RX J0018.3+1618 is consistent with a thermal plasma. Assuming a Raymond-Smith model with heavy metal abundance of 0.3 solar and the Galactic  $N_H$  value at the cluster position, the temperature of the plasma is  $kT = 1.6_{-0.4}^{+0.7}$  keV. This source has also been detected by ASCA and a preliminary analysis shows a spectrum consistent that derived from the ROSAT data. This is indicative of an intermediate redshift X-ray cool cluster of galaxies.

The redshifts of CL0016+16 and RX J0018.3+1618 are 0.5455 and 0.5506 respectively. All three X-ray clusters are, therefore, consistent with the redshift distribution observed in SA68. CL0016+16 and RX J0018.3+1618 have been suggested to be a bound system and possibly linked with the over-density of red galaxies in SA68 found by Koo (Hughes et al. 1995). Below we show in fact that the space distribution of the three clusters and those

galaxies in SA68 with spectroscopic redshifts are consistent with a supercluster viewed edge on with respect to the line of sight.

The orientation of clusters of galaxies has been suggested as a means of identifying coherent large scale structures (Binggelli 1982). Results derived from the optical distribution of galaxies remain inconclusive with West (1989) finding evidence for a correlation between cluster position angles on scales of up to  $45 \text{ h}^{-1}\text{Mpc}$  while Struble and Peebles (1985), using similar data, find no significant signal. Much of these uncertainties arise from the difficulty in separating cluster galaxies from contamination due to background sources (especially in the outer regions of a cluster). Determining the orientation of a cluster from the distribution of its X-ray emitting gas provides a more objective measure (Ulmer et al. 1989) since the gas better traces the cluster potential.

The position angles of the three X-ray sources were determined from the second moments of the outer isophotes of the X-ray photon distribution. The derived values for CL0016+16, RX J0018.3+1618 and RX J0018.8+1602 were  $39^\circ$ ,  $29^\circ$  and  $30^\circ$  East of North respectively. All three sources are, therefore, aligned with the galaxy distribution of SA68. As has been noted by Bond et al. (1996) the signature of superclustering will be strongest when the individual clusters are aligned.

## 5. Discussion: A “Great Wall” at $z = 0.54$

Combining the optical and X-ray data we have strong evidence for a coherent structure, at a redshift of  $z = 0.54$ , extending about one degree across the sky from the survey field SA68 through the cluster CL0016+16. At this redshift, this translates to a tangential size of  $12 \text{ h}^{-1}\text{Mpc}$ , a radial depth of  $31 \text{ h}^{-1}\text{Mpc}$  and a “thickness” of  $4 \text{ h}^{-1}\text{Mpc}$ . The positions of the galaxies and clusters within this volume are not randomly distributed but appear to lie in a planar distribution (i.e. their redshifts and angular distribution are strongly correlated).

To determine the true geometry of the galaxy distribution, i.e. whether it is better represented by an extended filament or a sheet of galaxies, we fit a two dimensional surface to the spectroscopic redshifts. The redshifts of the galaxies in SA68 and the three clusters are transformed to comoving distance and treated as independent points, we do not weight the cluster redshifts by the number of galaxies that have spectroscopic observations. The best fit to these data is a plane with an orientation  $40^\circ \pm 10^\circ$  East of North and an angle  $12^\circ \pm 2^\circ$  from the line of sight. Given that the redshift dispersion of the galaxies exceeds that expected for a cluster, we suggest that the structure we are observing is a sheet of galaxies oriented almost orthogonally to our line of sight.

As noted in §3, the dispersion in the photometric-redshift relation results in a dilution of the supercluster due to contamination by foreground and background galaxies. We cannot, therefore, map the full three-dimensional distribution of the supercluster. We can, however, determine whether the galaxy distribution is comparable to that observed in the local universe (i.e. if a structure similar to the “Great Wall” were to exist at  $z = 0.54$  what would its signature be). If we correct for the orientation of the galaxy distribution and determine the width orthogonal to the plane of the supercluster we derive a dispersion of  $433^{+85}_{-61}$  km s<sup>-1</sup>. This is consistent with the mean value of 300 km s<sup>-1</sup> determined by Ramella et al. (1992) for the “Great Wall”. Furthermore, if we assume that 30% of the galaxies within the redshift range  $0.5 < z < 0.6$  are indeed members of the supercluster, as suggested by the results of de Lapparent et al. (1991) from their analysis of the CfA redshift survey, we can estimate the surface density of the galaxies in the supercluster. Allowing for an inclination angle of 10 degrees to the line of sight and a luminosity distance of 1837 h<sup>-1</sup>Mpc we estimate the surface density of galaxies to be approximately 0.6 h<sup>2</sup> Mpc<sup>-2</sup>. This is only slightly higher than the values of 0.25–0.4 h<sup>2</sup> Mpc<sup>-2</sup> determined for the individual slices in the CfA redshift survey (de Lapparent et al. 1991). It would appear, therefore, that we have identified an intermediate redshift counterpart to the sheet-like supercluster structures observed in redshift surveys of the local universe.

Clearly the available data, while providing tantalizing evidence for large scale clustering at intermediate redshifts, do not map the full extent of this supercluster. The over-density in the spectroscopic redshifts encompasses the full extent of the survey field SA68. To determine the tangential distribution of galaxies at a redshift of 0.54 and, therefore, the true size of this supercluster we are engaged in followup photometric and spectroscopic observations of this region.

We would like to thank the referee for helpful comments that improved the clarity of this paper. We thank Richard Kron for providing the photographic plate for SA68 and help in the identification of the new X-ray cluster. We are grateful to Kron, Jeffrey Munn, Steven Majewski, Matthew Bershad, and John Smetanka for pre-publication access to the KPGRS catalogs and to Rogier Windhorst for the redshift of 54W084. We acknowledge Piero Rosati and Jack Hughes for useful discussions on the X-ray distributions in CL0016+16 and Gerry Luppino, Gordon Richards, Dan Vanden Berk and Michael Strauss for attempting optical followups of the SA68 region. AJC and AS acknowledge partial support from NSF grant AST-9020380, an NSF-Hungary Exchange Grant, the US-Hungarian Fund and the Seaver Foundation. DCK acknowledges support from the NSF grant AST 88-58203. AKR acknowledges support from NASA grant NAGS-2432. BH was supported in part by the National Science Foundation under a cooperative agreement with

the Center for Astrophysical Research in Antarctica (CARA), grant number NSF OPP 89-20223. CARA is a National Science Foundation Science and Technology Center. TM appreciates the hospitality of NASA Goddard Space Flight Center and the Johns Hopkins University during his visit. His visit was partially supported by USRA.

## REFERENCES

- Bingelli, B., 1982, A&A, 107, 338
- Bond, J.R., Kofman, L. & Pogosyan, D., 1996, Nature, 380, 603
- Broadhurst, T.J., Ellis, R.S., Koo, D.C. & Szalay, A.S., 1990, Nature, 343, 726.
- Burke, D.J., Collins, C.A., Nichol, R.C., Romer, A.K., Holden, B. P., Sharples, R. M., Ulmer, M. P., Proc. “Röntgenstrahlung from the Universe”, eds. Zimmermann, H.U., Trümper, J., and Yorke H., 1996, MPE Report 263
- Cohen, J.G., Hogg, D.W., Pahre, M.A., Blandford, R., 1996, ApJ, 462, L9
- Collins, C.A, Guzzo, G., Nichol, R.C., & Lumsden, S.L., 1995, MNRAS, 274, 1071
- Connolly, A.J., Csabai, I., Szalay, A.S., Koo, D.C., Kron, R.C. & Munn, J.A., 1995, AJ, 110, 2655
- Cowie, L.L., Songaila, A., Hu, E.M. & Cohen, J.G., 1996, AJ, in press
- Fasano, G. & Franceschini, A., 1987, MNRAS, 225, 155
- Geller, M.J. & Huchra, J.P., 1989, Science, 246, 897
- Giovanelli, R. & Haynes, M.P., 1993, AJ, 105, 1271
- Glazebrook, K., Ellis, R.S., Colless, M., Broadhurst, T., Allington-Smith, J. & Tanvir, N., 1995, MNRAS, 273, 157
- Gronwall, C. & Koo, D.C., 1995, ApJ, 440, L1
- Hughes J.P., Birkinshaw, M., Huchra, J.P., 1995, ApJ, 448, L93
- Koo, D.C., 1981, ApJ, 251, 75
- Koo, D.C., 1985, AJ, 90, 418
- Koo, D.C., 1986, AJ, 311, 651
- Kron, R.G., 1980, ApJS, 43, 305
- Landy, S.D., Sackett, S.A., Lin, H., Kirshner, R.P., Oemler, A.A. & Tucker, D., 1996, ApJ, 456, L1
- de Lapparent, V., Geller, M.J. & Huchra, J.P., 1991, ApJ, 369, 273
- Le Fevre, O., Crampton, D., Hammer, F., Lilly, S. J., & Tresse, L., 1994, ApJ, 423, L89
- Liddle, A.R., Lyth, D.H., Schaefer, R.K., Shafi, Q. & Viana, P.T.P., MNRAS, in press
- Lilly, S.J., Le Fevre, O., Crampton, D., Hammer, F. & Tresse, L., 1995, ApJ, 455, 50
- Munn, J. A., Koo, D. C., Kron, R. G., Majewski, S. R., Bershadsky, M. A., & Smetanka, J. J., 1995, ApJS, submitted

- Neff, S.G., Roberts, L. & Hutchings, J.B., 1995, ApJS, 99, 349
- Nichol, R.C., Holden, B.P., Romer, A.K., Burke, D.J., Collins, C.A., 1996, submitted to ApJ
- Peacock, J.A., 1983, MNRAS, 202, 615
- Ramella, M., Geller, M.J. & Huchra, J.P., 1992, ApJ, 384, 396
- Struble, M.F. & Peebles, P.J.E., 1985, AJ, 90, 592
- Szalay, A.S., Ellis, R.S., Koo, D.C. & Broadhurst, T.J., 1991, in Primordial Nucleosynthesis and Evolution of Early Universe, ed. K. Sato, J. Audouze (Kluwer, Japan), 435
- Ulmer, M.P., McMillan, S.L.W. & Kowalski, M.P., 1989, ApJ, 338, 711
- West, M.J., 1989, ApJ, 344, 535
- Willmer, C. N. A., Koo., D.C., Ellman, N., Kurtz, M.J. & Szalay, A.S., 1996, ApJS, in press
- Zabludoff, A.I., Geller, M.J., Huchra, J.P. & Ramella, M., 1993, AJ, 106, 1301

Fig. 1.— The redshift distribution of galaxies in the Selected Area SA68 for those galaxies in the Koo and Kron spectroscopic sample with  $B_J < 23$ . The solid line represents the expected distribution of redshifts for this sample assuming no clustering. The expectation value for the number of galaxies between  $0.530 < z < 0.555$  is  $3.54 \pm 3.7$ . The observed number of galaxies within this redshift range is 14, a factor of four larger.

Fig. 2.— The spatial distribution of those galaxies with spectroscopic redshifts between  $0.530 < z < 0.555$ , in SA68, is shown in Fig 2a. The solid line shows the extent of the SA68 survey field. The distribution of galaxies with photometric redshifts in the range  $0.49 < z < 0.59$  is given in Fig 2b. The spectroscopic and photometric samples of galaxies form a linear distribution passing from the South-West of SA68 through to the North-East with position angles of  $27.2^\circ$  and  $40.3^\circ$  (East of North) respectively. The positions of the previously identified X-ray clusters CL0016+16 and RX J0018.3+1618 are shown in both figures together with the new cluster RX J0018.8+1602. The position angle of the photon distribution for these X-ray clusters are  $39^\circ$ ,  $29^\circ$  and  $30^\circ$  respectively.

**Figure 3 can be found as a compressed postscript file (4MB) at <http://tarkus.pha.jhu.edu/~ajc/papers/supercluster/Figure3.ps.Z>**

Fig. 3.— The ROSAT PSPC X-ray contours for RX J0018.8+1602 are overlaid on a 4m  $B_J$  photographic plate of SA68. A local bore sight correction has been applied to the X-ray data based on the position of three stars. The wavelet analysis of the field shows the X-ray distribution to be more extended than the radially dependent PSF at greater than the three sigma level. The peak in the X-ray photon distribution is coincident with an over-density of faint galaxies ( $B_J \sim 23$ ) with the central galaxy appearing elliptical. The arrow indicates the position of the radio galaxy 54W084 at a redshift of  $z = 0.544$ . The position of this radio source is within one arcmin of the center of the X-ray cluster and is contained within the outer isophotes. If we assume the radio galaxy is a member of the cluster the X-ray luminosity corresponds to  $4.25 \times 10^{43}$  ergs  $s^{-1}$ . This is approximately 13% of the luminosity of CL0016+16.





